



“The Space Shuttle Columbia Preservation Project – The Debris Loan Process”

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Columbia Preservation Project

- Purpose:
 - Provide a process for loan of Columbia debris to qualified researchers and technical educators
 - Aid in advanced spacecraft design and flight safety development
 - Advance the study of hypersonic re-entry to enhance ground safety.
 - Train and instruct accident investigators
 - Establish an enduring legacy for Space Shuttle Columbia and her crew.



Columbia Recovery Office

- The Columbia Recovery Office was formed at JSC at the conclusion of recovery operations on May 1st
- In October the SFOC contract was changed to incorporate the Columbia Recovery Office and Preservation, subsequently the CRO was transferred to USA/KSC on October 6th
- Using (866) 446-6603, this is the same phone number used throughout the recovery, anyone can call about debris
 - Phone rings in OSB 6th floor, USA GO Program Office
 - Information is taken and input into Shuttle Interagency Debris Database (SIDDs). Name, contact #s, location
 - Any available pictures or information is forwarded to PH/GO for determination of Orbiter hardware or not
 - If designated hardware and within 25 miles of the current known debris path Weston (EPA contractor that participated in recovery) will recover and transport to NASA Palestine Balloon facility. Subsequently items are shipped to KSC
 - Otherwise the person is directed to transport item to local authority and contact NASA where we give Fed Ex shipping number and send to KSC
 - Once at KSC item is inventoried into Reconstruction/Preservation database and placed on 16th floor of VAB

Debris Check-in Process

Receiving Materials (CRO/Weston)

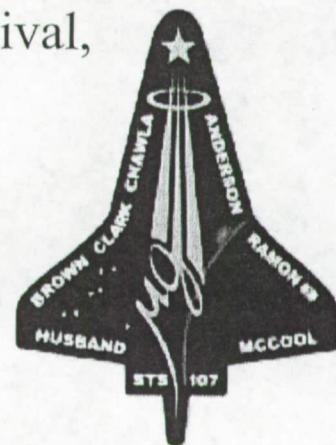
- Toxic Vapor Checks are performed on all items before processing

Quality Receiving

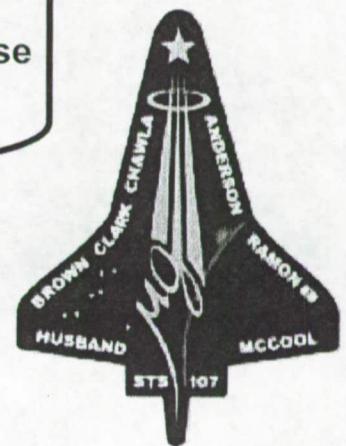
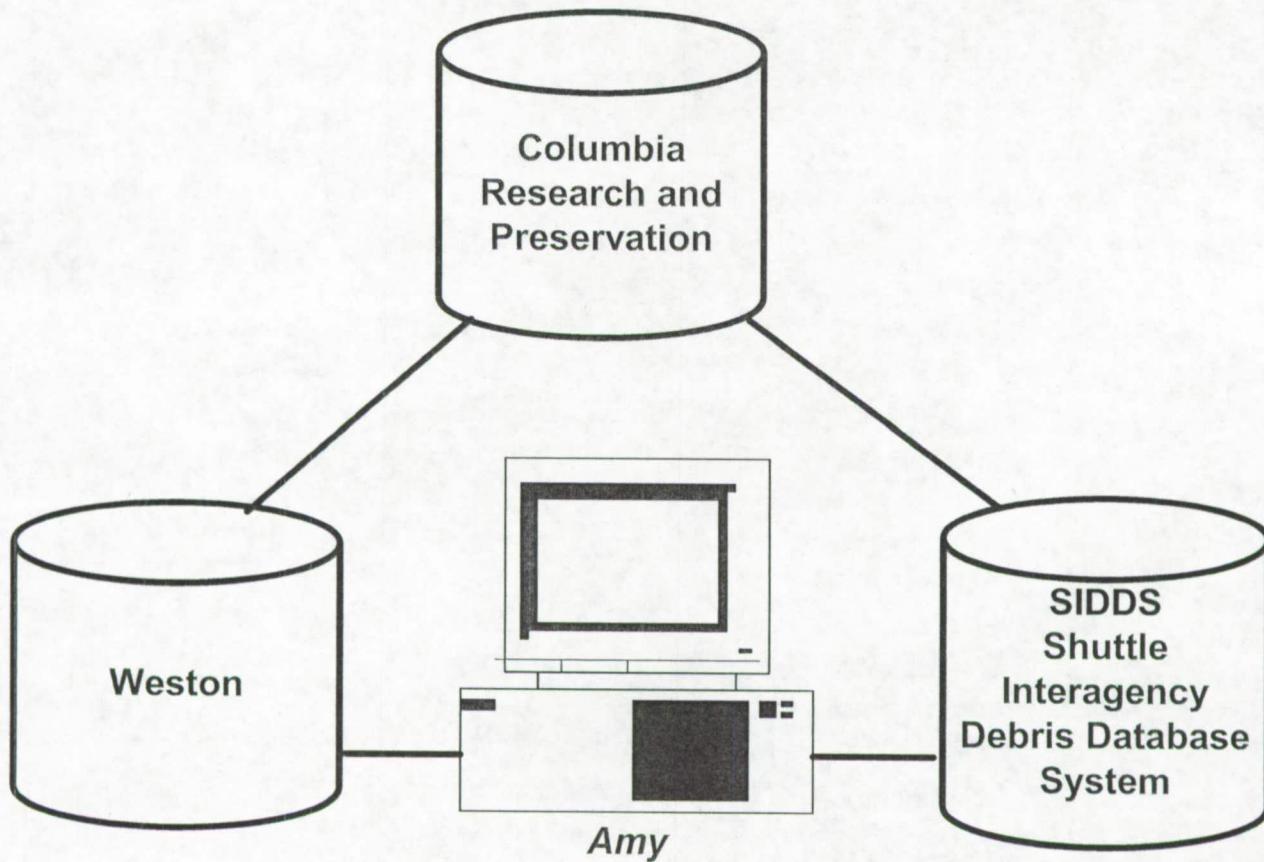
- Debris items are:
 - Photographed bar-coded and tagged
 - Entered into CRDS. Multiple items are separated into parent/child relationships
 - Data records include item description, time and date of arrival, longitude/latitude and date and time of recovered area.

Movement of Debris

- Handler assign items to locations for storage according to size, weight, and system identification



Database Interface



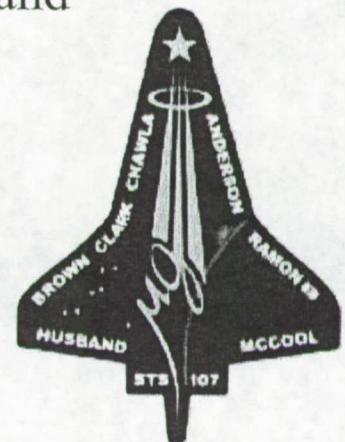
Coordination of Debris Requests

Internal to Space Shuttle Program

- Requestor fill out Debris Loan Request and contacts Columbia Research and Preservation Office for validation and approval.
- Forward to following for release approval
 - ✚ Space Shuttle Orbiter Project Office (OPO) Manager (JSC/MV)
 - ✚ Flight Crew Operations Directorate (FCOD)/ Astronaut Office if crew module debris is involved.
 - ✚ Space Shuttle Deputy Program Manager at KSC (MK)
 - ✚ Columbia Research and Preservation Office for database entry and coordination for shipping

Shipping of Material

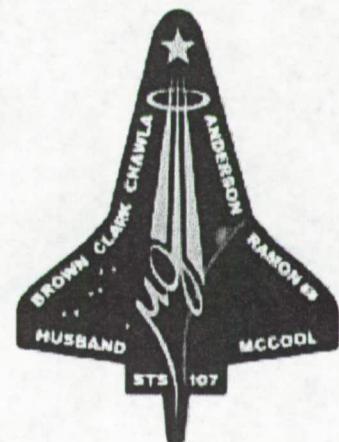
- Coordinated with USA logistics.
 - ✚ Generate DD1149
 - ✚ Tracking number entered into CRDS



Coordination of Debris Requests

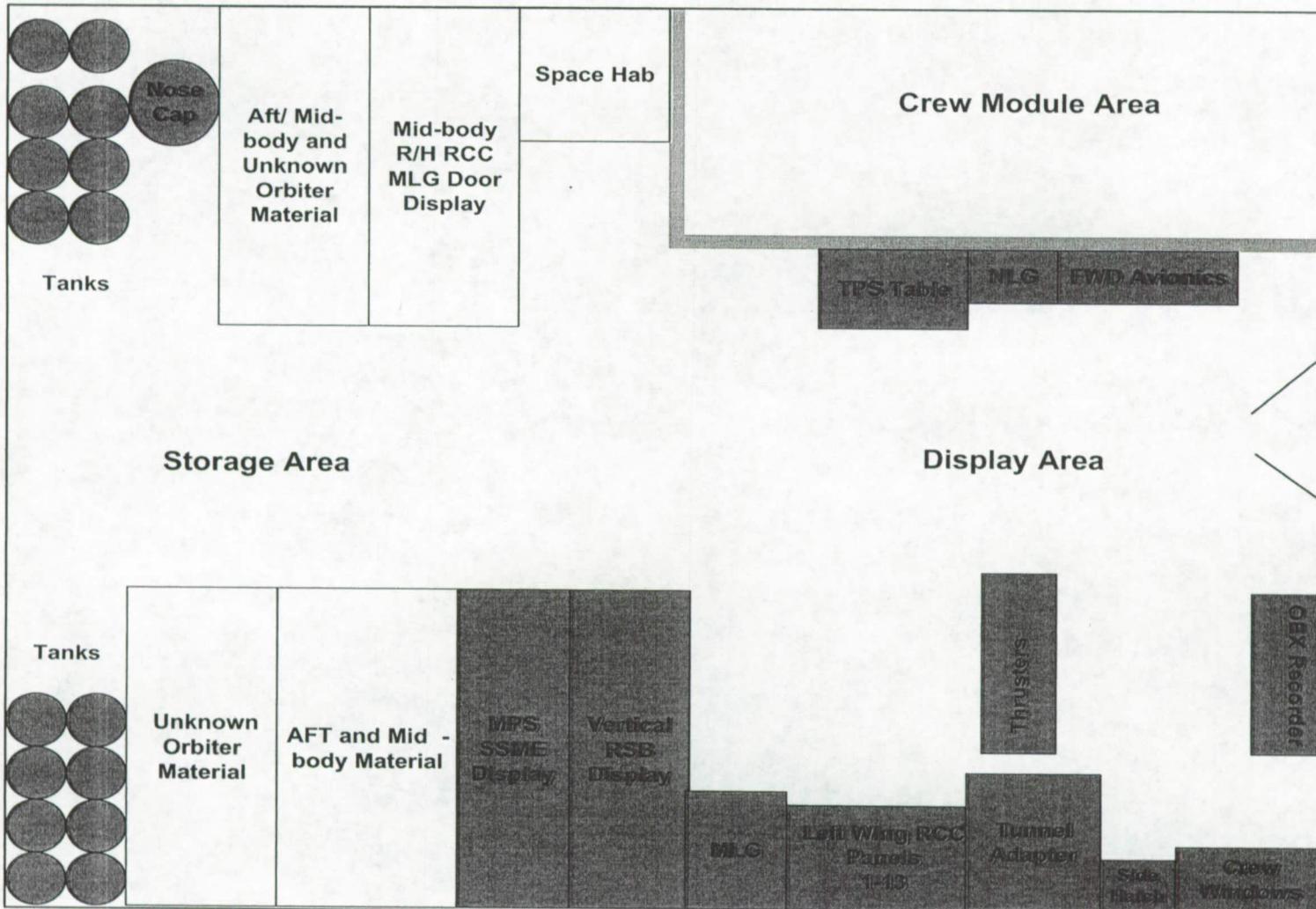
External to Space Shuttle Program

- The NASA Review and Approval Committee will consist of the following individuals for concurrence:
 - ✚ Designated NASA Approval Authority (Space Shuttle Program Manager)
 - ✚ Technical Expert (Subsystem Manager)
 - ✚ NASA expert in research process.
 - ✚ NASA Legal
 - ✚ NASA Education (education-related request)
 - ✚ FCOD/Astronaut Office





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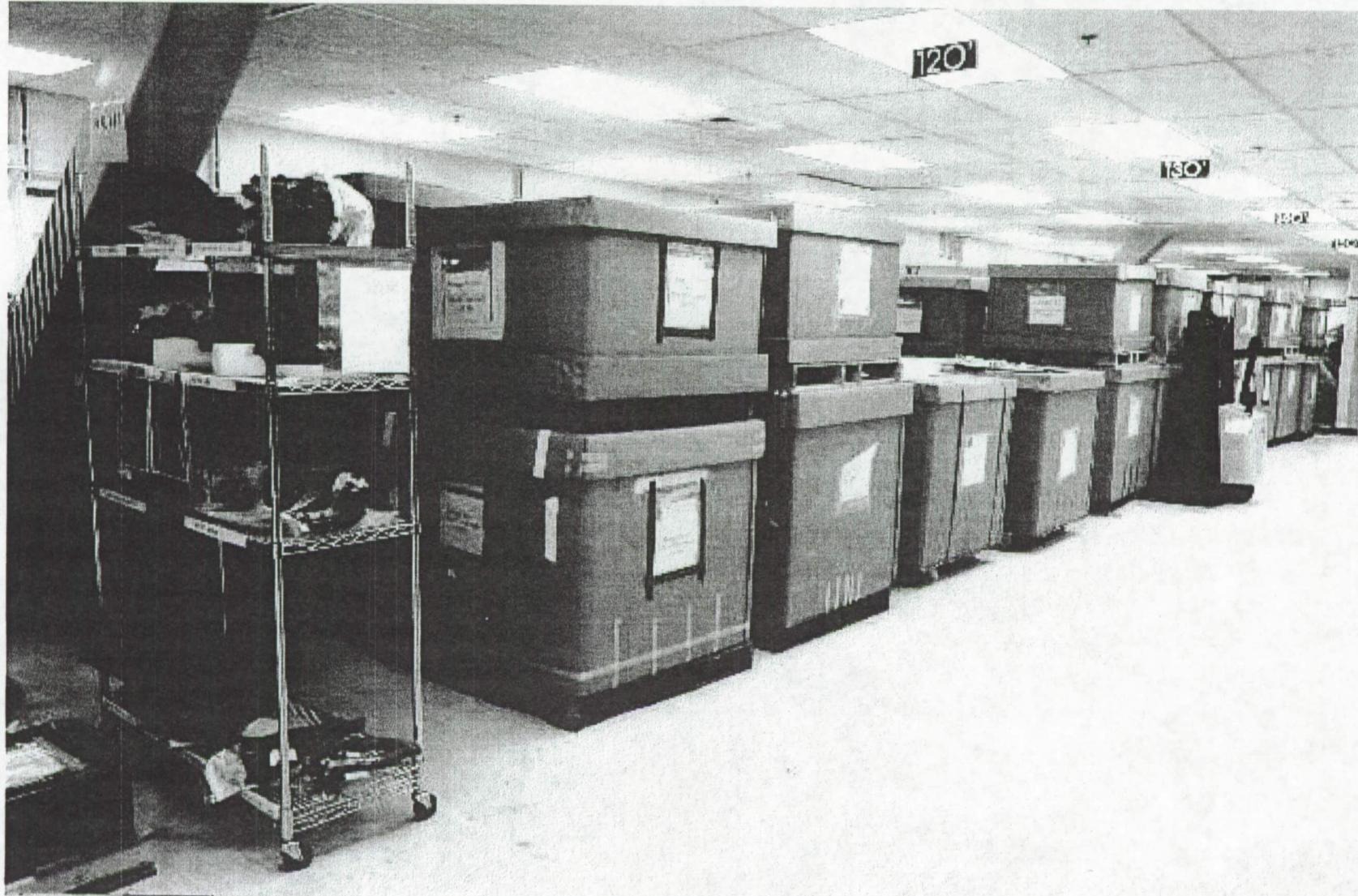


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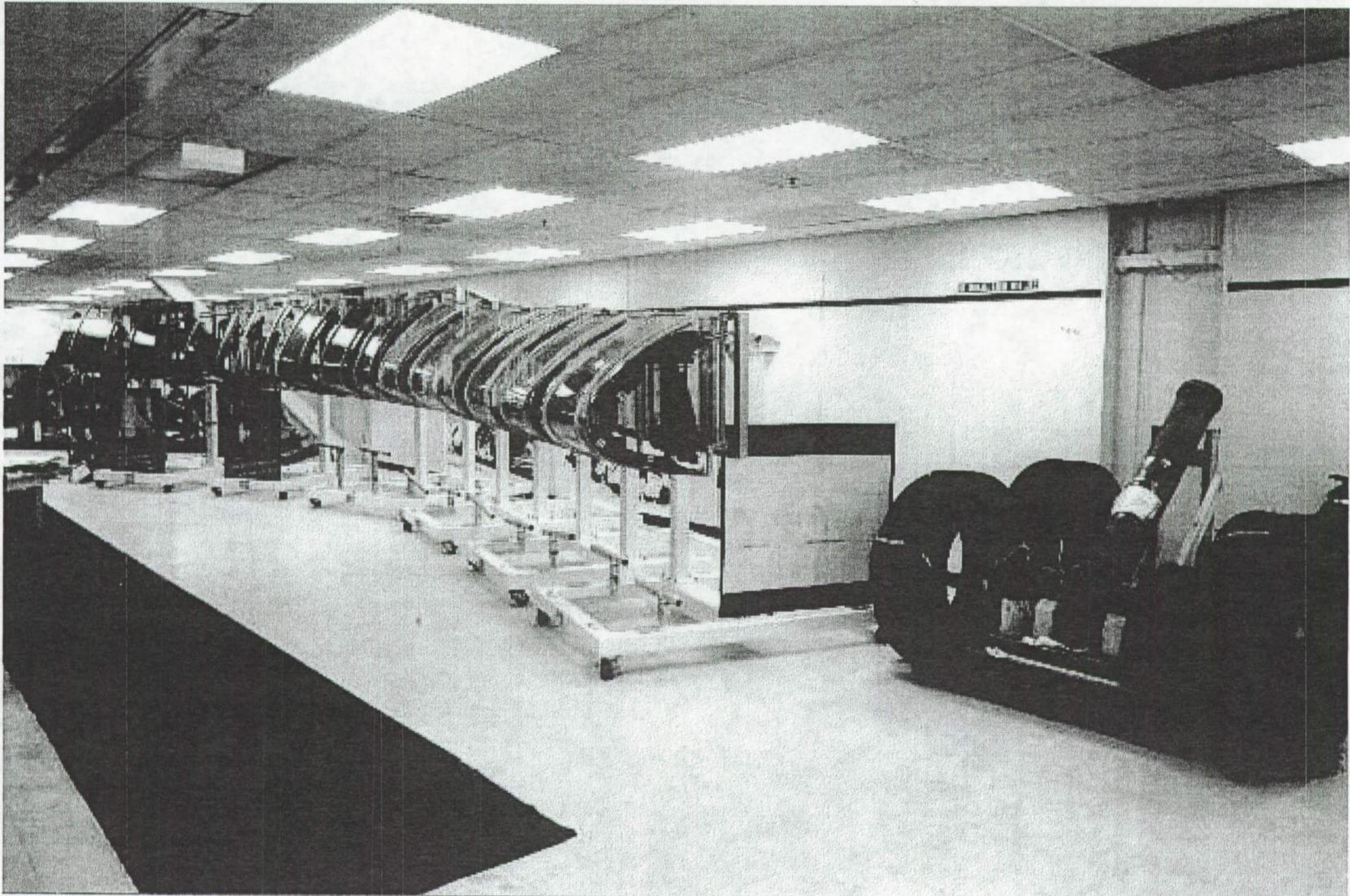


Columbia Preservation Project



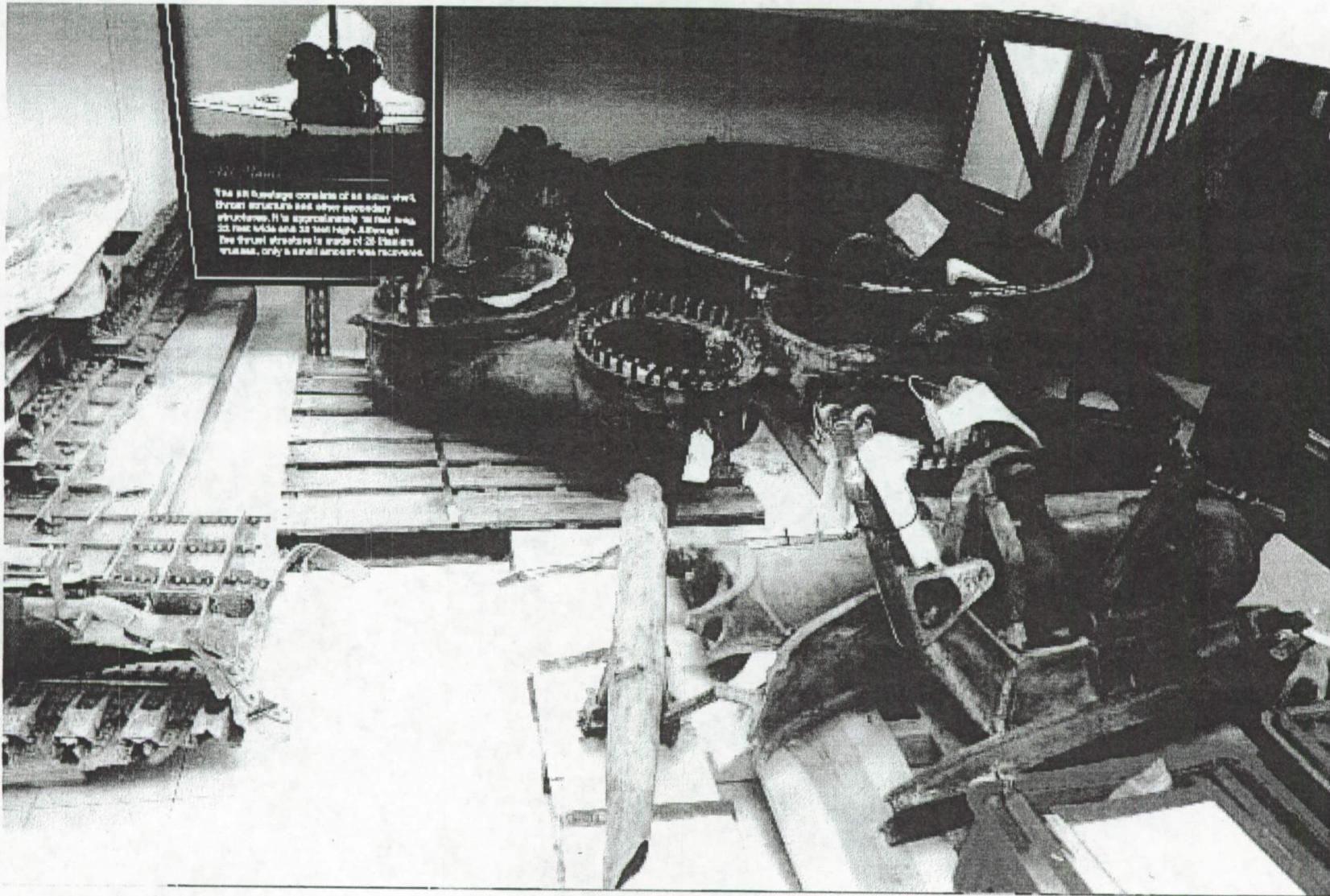


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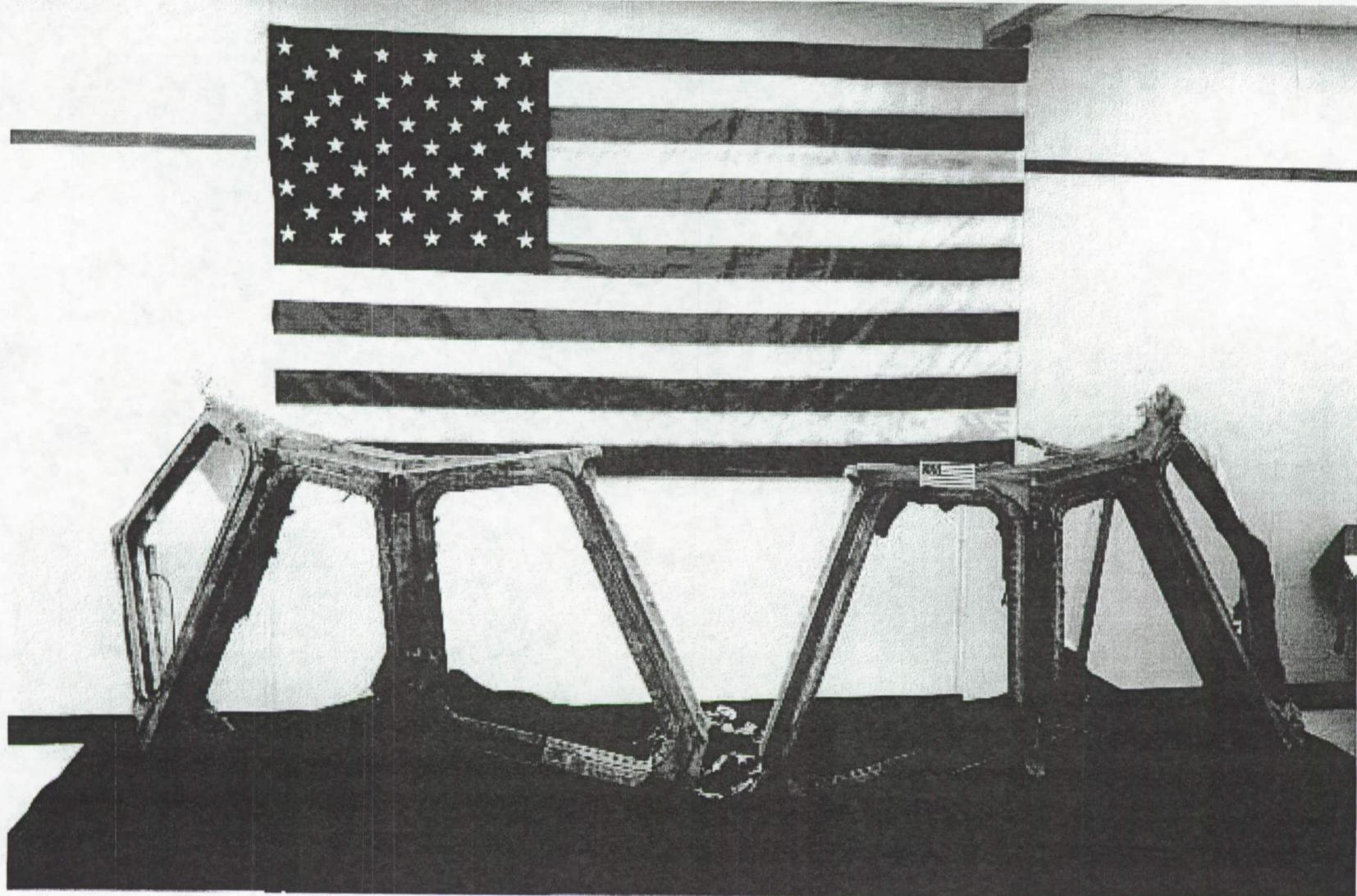
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The shuttle consists of an upper orbital structure and other secondary structures. It is approximately 100 feet long, 30 feet wide and 35 feet high. Although the thermal insulation is made of 30 different materials, only a small amount was recovered.



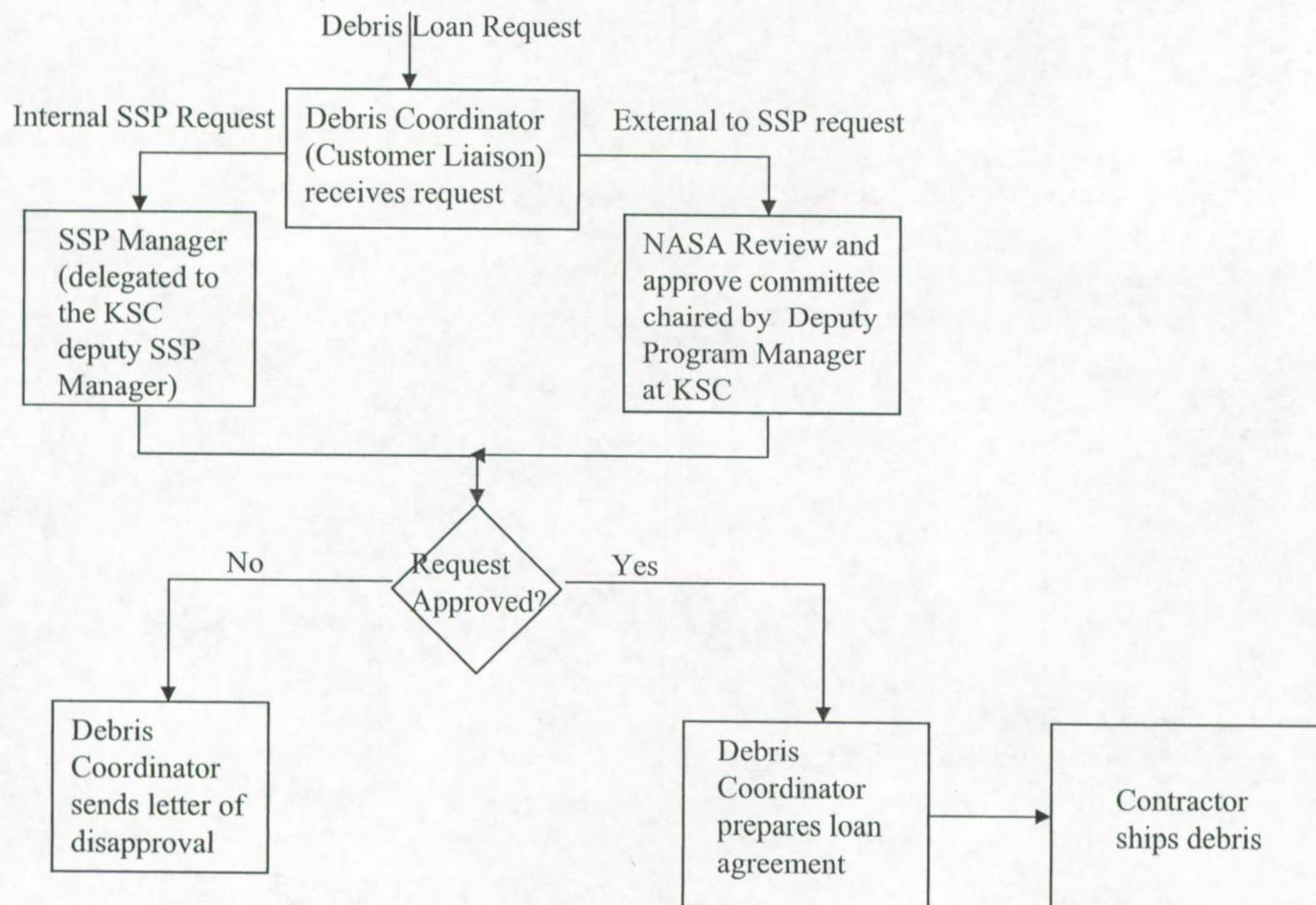
Columbia Preservation Project





Columbia Preservation Project

Columbia Debris Loan Process





LEHIGH
UNIVERSITY



*The Columbia Debris Failure Analysis
Program at
Lehigh University*

*R. M. Deacon
A. R. Marder*

AeroMat 2005

Mat 338 – Failure Analysis Reports

- Capstone senior level materials science and engineering course
- Requires students to draw on knowledge learned in previous 3½ years
- Discuss mechanisms and identification of various failure modes in lectures
- Hands on demonstrations of actual failures in laboratory session
- Culminates in independent failure analysis project

Why Study Columbia Debris?

- *Excellent example of real life failure*
 - Complex materials experienced severe loads and temperatures during hypersonic re-entry
 - Unknown sample history / background
 - Little data on loads and conditions at failure
 - Sample contamination issues
- *Opportunity to turn tragic event into an educational learning tool*

The Process

1. Assignment of debris
2. Observations and planning
3. Submission of cut plans
4. Sectioning and metallography
5. Light optical microscopy
6. Scanning electron microscopy / EDS

Emphasized throughout –

DOCUMENTATION and SECURITY

Sample Cut Plan

I. Detonate Discrepancies

Deton 40091 is a heterogeneous piece of the Columbia accident. Figure 1 shows photographic snapshots of the top surface of the debris. Fig. 1(a) is of the bottom surface of the debris. Fig. 1(b).

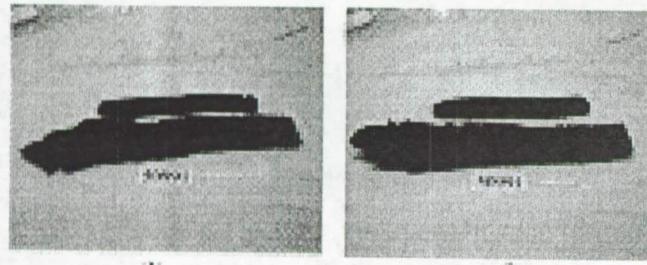


Figure 1. Photographic images of debris 40091, showing the top and bottom surfaces.

II. Cut Plan

Four different sections are to be cut from this debris 40091 for future analysis. Figure 2 shows the points that are to be made in the initial cuts of debris 40091. Sections 1 and 2 have a thickness of one centimeter to facilitate easier differentiation in segregation, between the different structural types of the debris in the aggregate. A

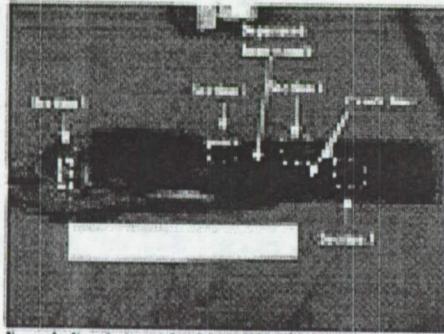


Figure 2. Cut plan for debris 40091. These different sections will be removed from the debris for microscropic analysis.

one centimeter, and open the surface showing fissures. Once (program 2) has an access to an underlying surface for the type dimensional reference. This will need to be performed using optical microscopy (OM) technique. Determination of the inclusion using scanning electron microscopy (SEM) may also be performed in order to identify the fiber inclusion, if any exists. To accomplish this, the parallel to sample axis of segmented homogeneous material, as shown in Figure 1, is required. Figure 2, reveals that a section down the outer part of the debris, with a limited number of fibers, is a characteristic of the program may help in the removal of the upper portion of fibers and, perhaps, the cause of failure for the separation of debris. Figure 4, which is a section of the debris, contains the fiber and material of debris 40091, will be an ideal for the comparison of the fiber density and diameter of debris 40091. SEM image characteristics of the fiber are not found. In addition, a cross-sectional view of the region will allow for a more detailed analysis of the fiber and, perhaps, the fiber itself.

Photographs and segmented images of each of the segmented subsections are to be removed during the cut up process on debris 40091. Figure 3 shows a close-up view of one of the debris material to corroborate the program. The segmented material included the debris in Figure 2. The segmented debris can be used to differentiate and the various areas which include numerous carbon fiber components can be more clearly seen in the image. One should notice that there seems to be a major layer orientation between the top and bottom area of the debris. A thin material, which is an interlayer between the top and bottom layers of the debris, is also possibly analyzed using EDS, and possibly SEM, in order to determine the origin of the material and orientation of the debris.

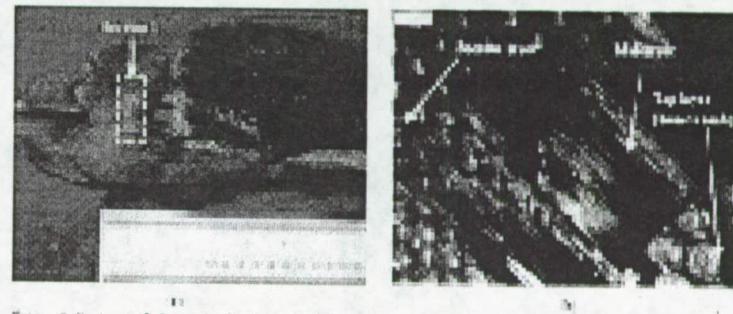
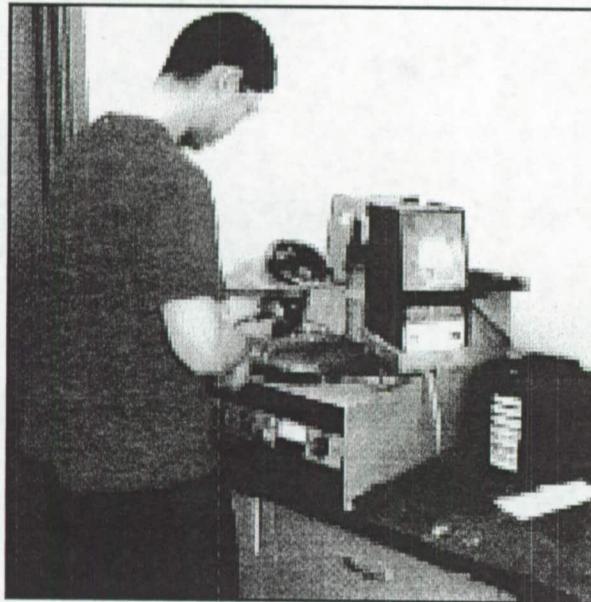


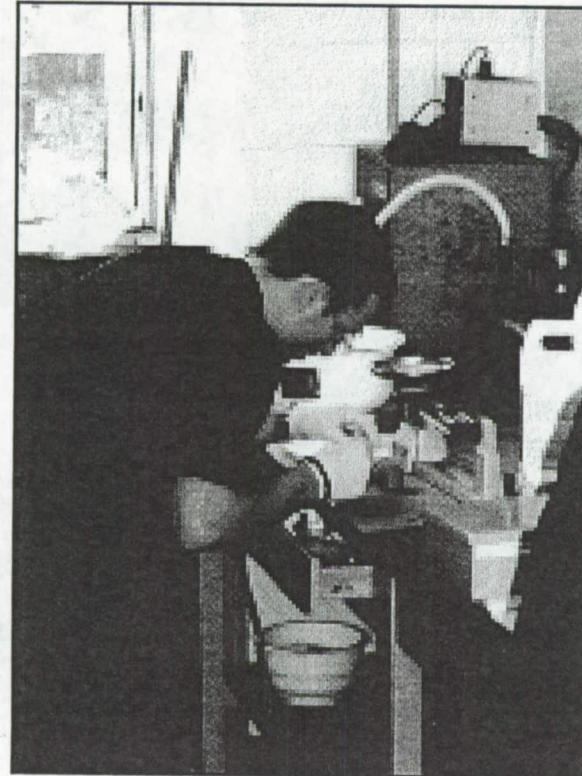
Figure 3. Close-up photographs of debris 40091. (a) The right photograph is a cross-section of the debris. The debris are broken into layers to identify each material and because some of the debris areas are enclosed by the fiber of a mesh layer of material such as carbon fiber or carbon materials.

An optical photomicrograph of a thin, solid, and translucent carbon fiber is shown in Figure 4. The image indicates some of the signs of damage, such as signs of deformation or failure of the concentric layer of the fiber. The thinner section of the fiber will be

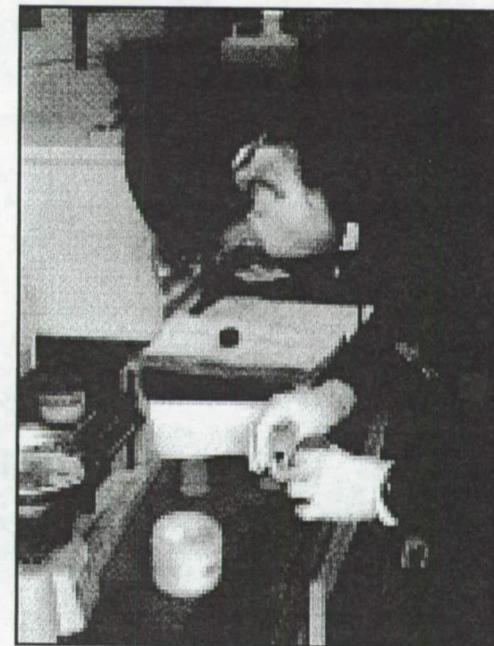
Sample Preparation



*Polishing Aluminum
Samples*

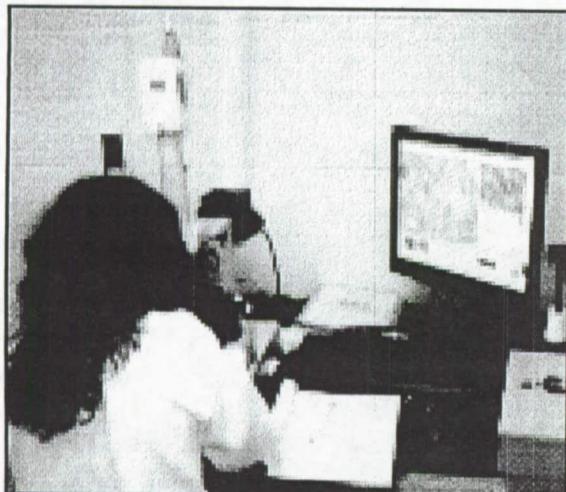


*Epoxy
Impregnation*

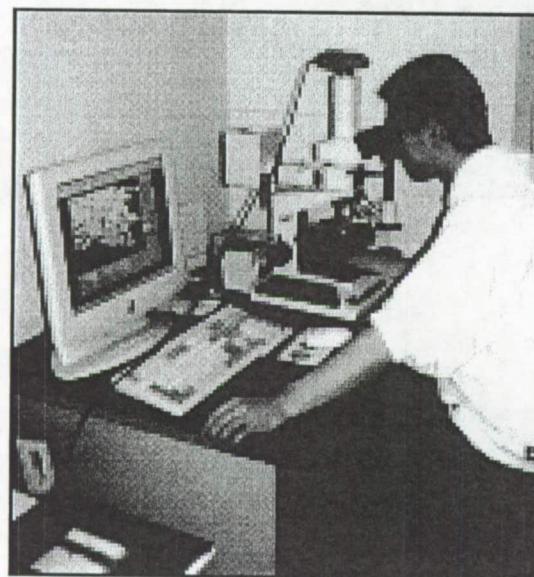


*Mounting Tile
Sections*

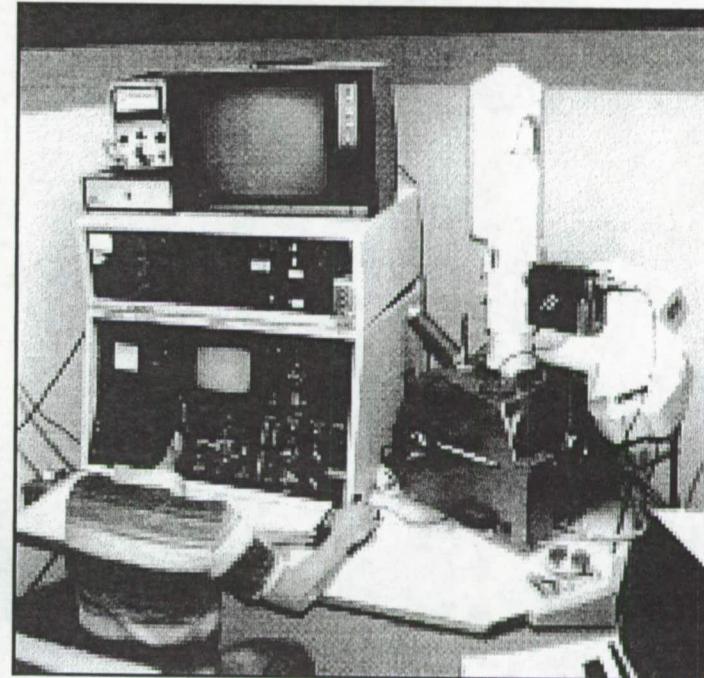
Image Analysis, LOM, SEM



*Digital Image
Analysis*



*Digital Image
Archiving
System*



*Dedicated
Undergraduate
Scanning Electron
Microscope*

Media Coverage

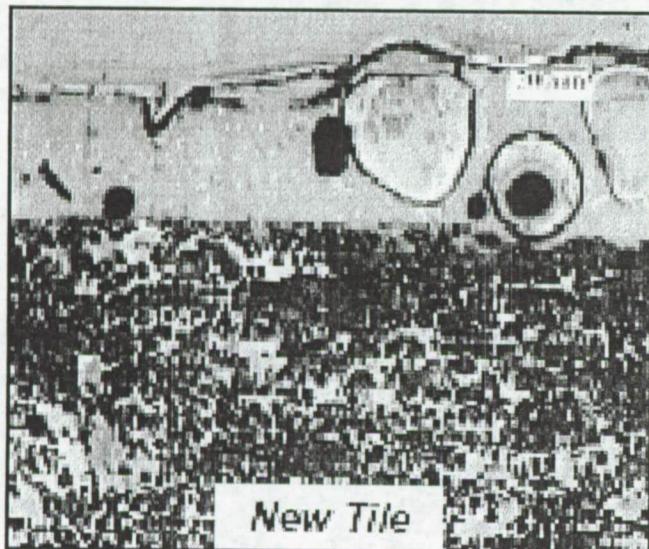
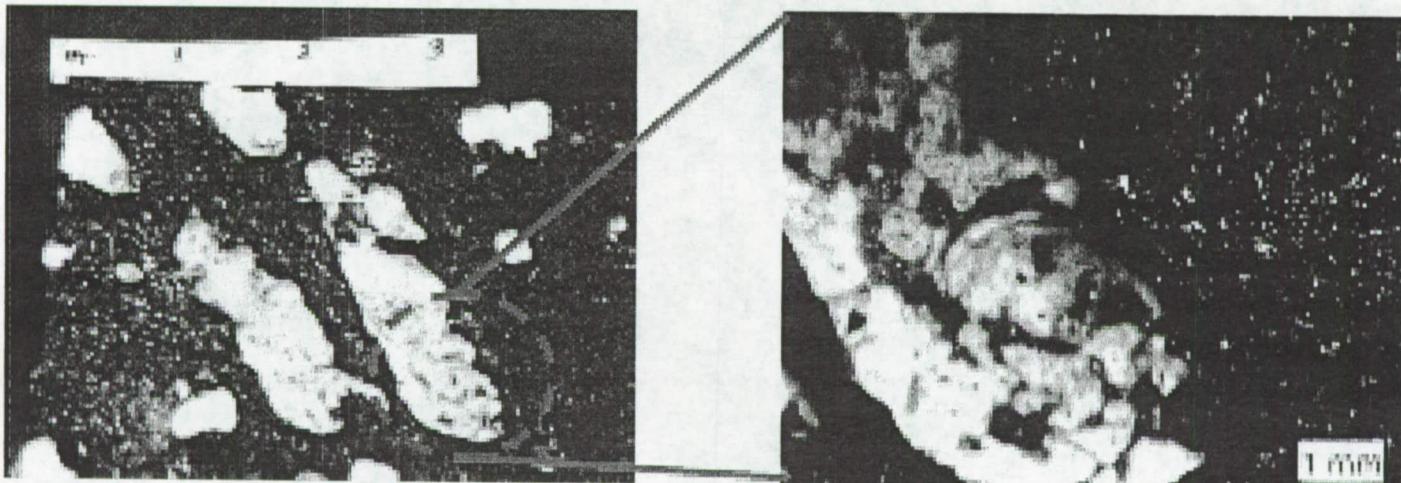
- Associated Press
- Fox Philadelphia
- CBS Harrisburg
- Lehigh Valley Tempo
- *The Morning Call*



*Professional
development experience*

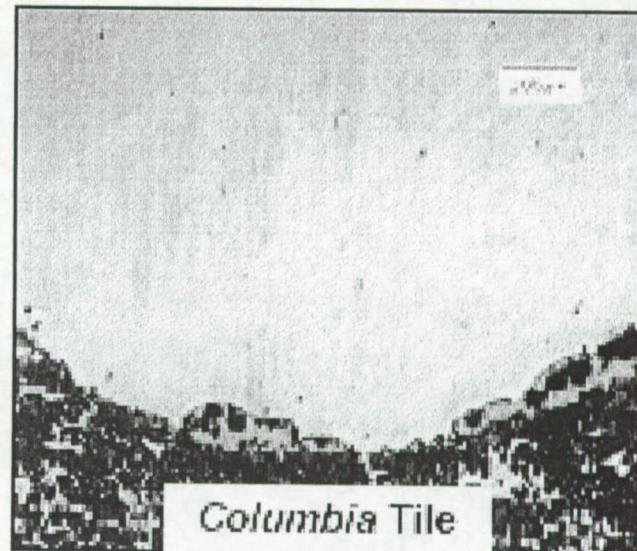
Analysis of Columbia Tile:

Slumping of RCG Layer



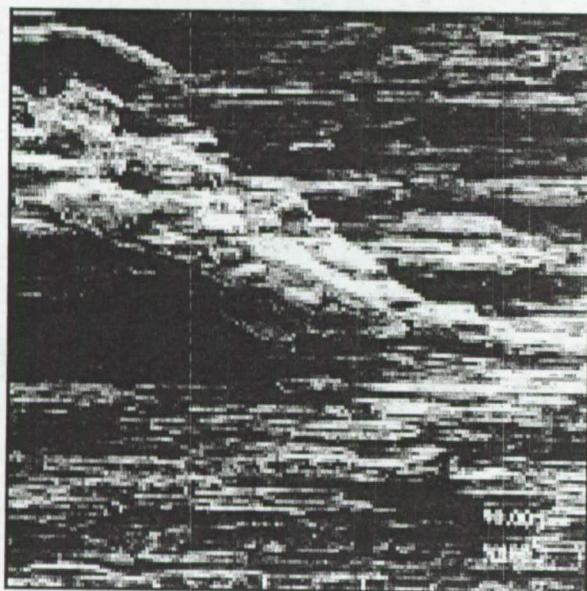
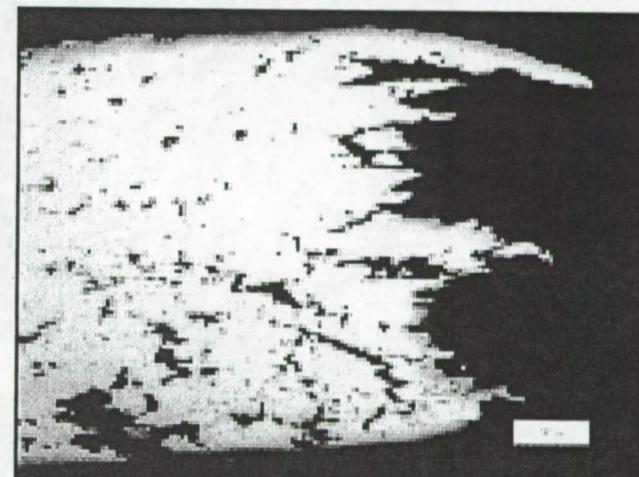
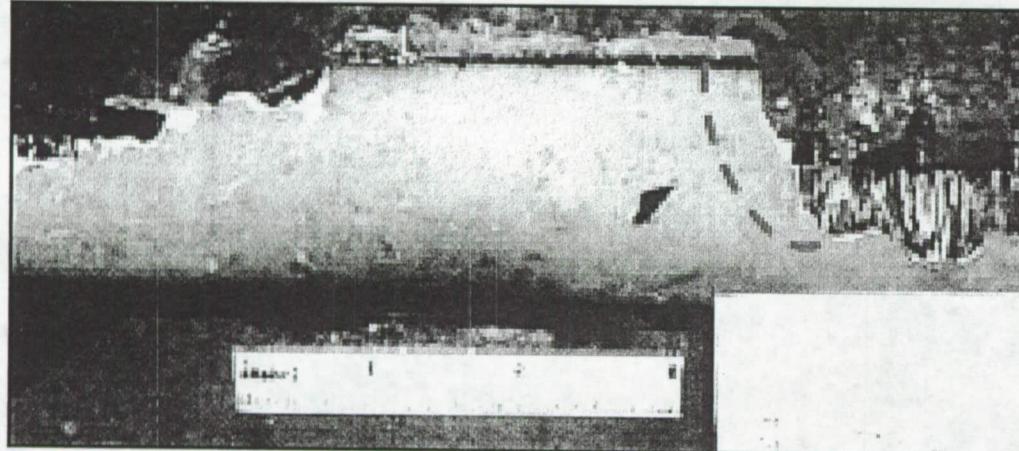
New Tile

*Comparison of
RCG Layer on
New and
Recovered
Columbia
Tiles*



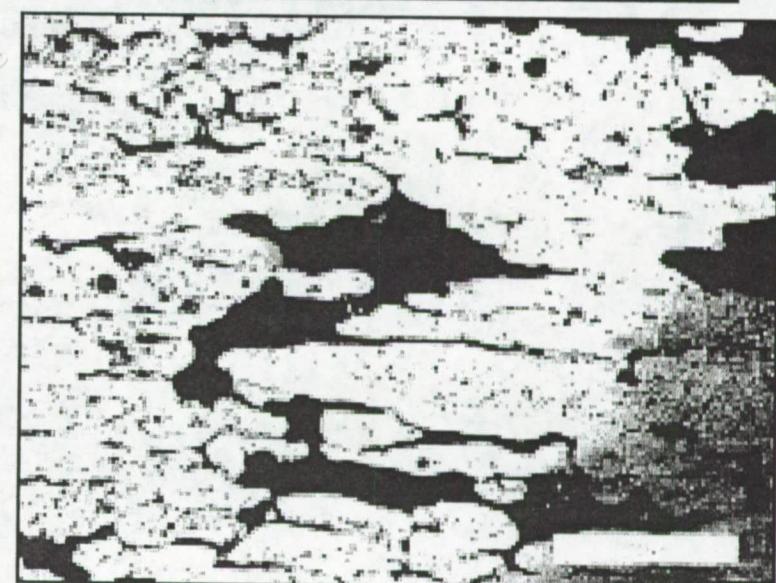
Columbia Tile

Analysis of Al Upper Spar Fitting: Void Formation and Intergranular Fracture

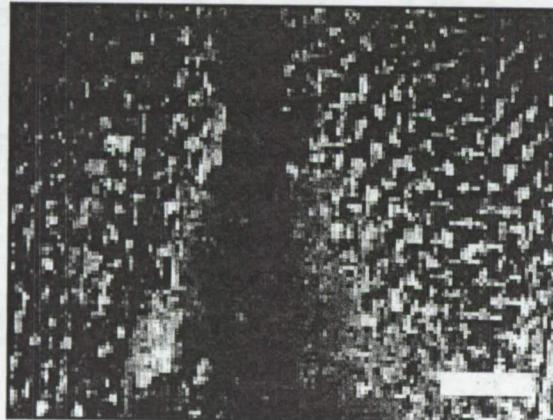
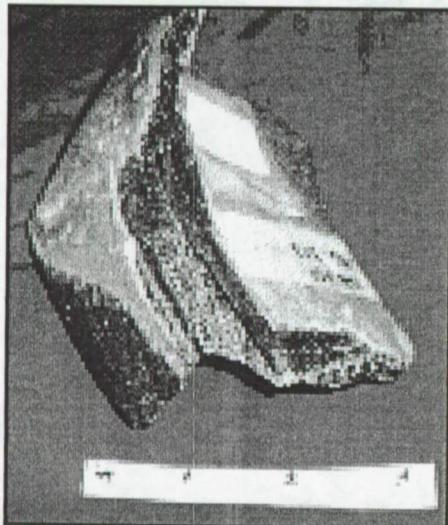


*Void
Formation*

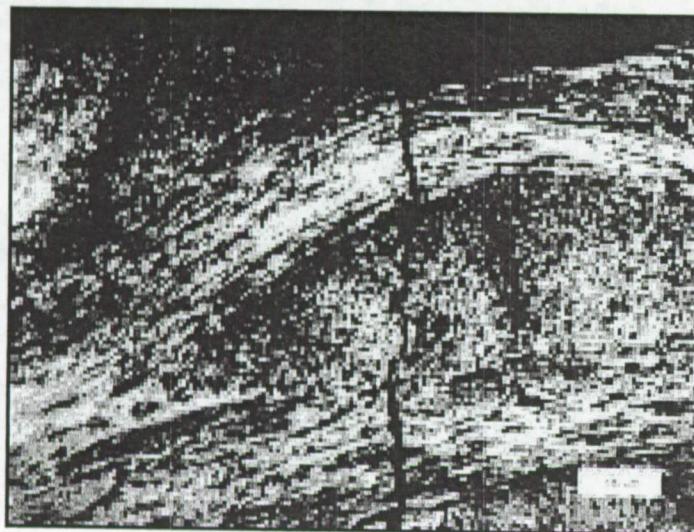
*Intergranular
Fracture*



Analysis of RCC T-Seal: SiC Erosion and Cracking



*Erosion
of SiC
Layer*



*Cracks
through
SiC layers*

*Brittle
fracture of
fibers*



Conclusions

- Excellent project for failure analysis class
- Students experience
 - Real life failure analysis
 - Working in secure environment
 - Interactions with the media
- Student analysis of debris adds to NASA knowledge base
- Program should be continued in the future